

**We claim:**

- 1           1.    A process for cleaving one or more  
2 hydroperoxides selected from the group consisting of s-  
3 butylbenzene hydroperoxide, cumene hydroperoxide, and  
4 combinations thereof, the process comprising:  
5           feeding a cleavage reaction feed to a cleavage  
6           reactor to produce a cleavage reaction mixture  
7           comprising the one or more hydroperoxides; and  
8           subjecting the cleavage reaction mixture to cleavage  
9           reaction conditions effective to produce a  
10          cleavage reaction product comprising phenol and  
11          one or more components selected from the group  
12          consisting of methyl ethyl ketone (MEK),  
13          acetone, and combinations thereof;  
14          wherein the cleavage reaction conditions comprise a  
15          cleavage reaction temperature of less than 75 °C  
16          which is sufficiently high to cleave a majority  
17          of the one or more hydroperoxides but  
18          sufficiently low to produce a first quantity of  
19          non-recoverable byproducts from components  
20          selected from the group consisting of  
21          dimethylbenzyl alcohol (DMBA), ethyl methyl  
22          benzyl carbinol (EMBA), and combinations  
23          thereof, the first quantity of said non-  
24          recoverable byproducts being less than a second  
25          quantity of said non-recoverable byproducts  
26          produced by the same process at a cleavage  
27          reaction temperature of 75 °C or higher.
- 1           2.    The process of claim 1 wherein:  
2           wherein said cleavage reaction feed comprises from  
3           about 0.5 wt.% to 2 wt.% water and a ketone  
4           stream selected from the group consisting of an  
5           acetone stream, a MEK stream, and a mixed  
6           acetone/MEK stream; and  
7           said cleavage reaction conditions comprise feeding  
8           the first cleavage reaction feed to a first  
9           cleavage reactor and subjecting the first

10 cleavage reaction feed to first cleavage  
11 reaction conditions effective to produce a  
12 first cleavage reaction mixture comprising a  
13 first cleavage reaction product, and feeding  
14 the first cleavage reaction product to a second  
15 cleavage reactor to produce a second cleavage  
16 reaction mixture and subjecting the second  
17 cleavage reaction mixture to second cleavage  
18 reaction conditions effective to produce a  
19 second cleavage reaction product.

1 3. The process of claim 2 wherein the second  
2 cleavage reaction conditions comprise a second cleavage  
3 reaction temperature effective convert DMBA to  $\alpha$ -methyl  
4 styrene and to convert EMBA to one or more compound  
5 selected from the group consisting of  $\alpha$ -ethyl styrene  
6 (AES), 2-phenyl-2-butene (2P2B), and combinations  
7 thereof.

1 4. The process of claim 1 wherein said first  
2 cleavage reaction conditions comprise feeding to the  
3 first cleavage reaction mixture an acid catalyst  
4 effective to catalyze the cleavage of hydroperoxides  
5 selected from the group consisting of s-butylbenzene  
6 hydroperoxide, cumene hydroperoxide, and combinations  
7 thereof.

1 5. The process of claim 2 wherein said first  
2 cleavage reaction conditions comprise feeding to the  
3 first cleavage reaction mixture an acid catalyst  
4 effective to catalyze the cleavage of hydroperoxides  
5 selected from the group consisting of s-butylbenzene  
6 hydroperoxide, cumene hydroperoxide, and combinations  
7 thereof.

1 6. The process of claim 3 wherein said first  
2 cleavage reaction conditions comprise feeding to the  
3 first cleavage reaction mixture an acid catalyst  
4 effective to catalyze the cleavage of hydroperoxides  
5 selected from the group consisting of s-butylbenzene  
6 hydroperoxide, cumene hydroperoxide, and combinations  
7 thereof.

1           7.    The process of claim 4 wherein the acid  
2 catalyst is selected from the group consisting of  
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,  
4 and phosphoric acid.

1           8.    The process of claim 5 wherein the acid  
2 catalyst is selected from the group consisting of  
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,  
4 and phosphoric acid.

1           9.    The process of claim 6 wherein the acid  
2 catalyst is selected from the group consisting of  
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,  
4 and phosphoric acid.

1           10.   The process of claim 4 wherein the acid  
2 catalyst comprises sulfuric acid.

1           11.   The process of claim 5 wherein the acid  
2 catalyst comprises sulfuric acid.

1           12.   The process of claim 6 wherein the acid  
2 catalyst comprises sulfuric acid.

1           13.   The process of claim 6 wherein the first  
2 cleavage reactor and the second cleavage reactor are  
3 selected from the group consisting of plug-flow reactors,  
4 plug-flow reactors with recycle, and continuous stirred  
5 tank reactors.

1           14.   The process of claim 12 wherein the first  
2 cleavage reactor and the second cleavage reactor are  
3 selected from the group consisting of plug-flow reactors,  
4 plug-flow reactors with recycle, and continuous stirred  
5 tank reactors.

1           15.   The process of claim 6 wherein the first  
2 cleavage reactor is a stirred tank reactor comprising  
3 internal or external heat exchangers effective to  
4 maintain the first cleavage reaction mixture at a first  
5 cleavage reaction temperature.

1           16.   The process of claim 12 wherein the first  
2 cleavage reactor is a stirred tank reactor comprising  
3 internal or external heat exchangers effective to  
4 maintain the first cleavage reaction mixture at a first  
5 cleavage reaction temperature.

1           17. The process of claim 6 wherein the first  
2 cleavage reactor is a pipeline loop reactor comprising  
3 one or more heat exchangers effective to maintain a first  
4 cleavage reaction mixture at a first cleavage reaction  
5 temperature.

1           18. The process of claim 12 wherein the first  
2 cleavage reactor is a pipeline loop reactor comprising  
3 one or more heat exchangers effective to maintain a first  
4 cleavage reaction mixture at a first cleavage reaction  
5 temperature.

1           19. The process of claim 1 wherein the first  
2 cleavage reaction conditions comprise  
3           a first cleavage reaction temperature of from about  
4           45°C to about 70°C;  
5           a first cleavage reaction pressure sufficiently high  
6           to maintain the first cleavage reaction mixture  
7           in the liquid phase; and,  
8           a first cleavage reaction residence time effective  
9           to cleave about 95% or more of s-butylbenzene  
10          hydroperoxide in the first cleavage reaction  
11          mixture to phenol and MEK and to cleave about  
12          95% or more of cumene hydroperoxide in the  
13          first cleavage reaction mixture to phenol and  
14          acetone.

1           20. The process of claim 2 wherein the first  
2 cleavage reaction conditions comprise  
3           a first cleavage reaction temperature of from about  
4           45°C to about 70°C;  
5           a first cleavage reaction pressure sufficiently high  
6           to maintain the first cleavage reaction mixture  
7           in the liquid phase; and,  
8           a first cleavage reaction residence time effective  
9           to cleave about 95% or more of s-butylbenzene  
10          hydroperoxide in the first cleavage reaction  
11          mixture to phenol and MEK and to cleave about  
12          95% or more of cumene hydroperoxide in the  
13          first cleavage reaction mixture to phenol and  
14          acetone.

1           21. The process of claim 3 wherein the first  
2 cleavage reaction conditions comprise  
3           a first cleavage reaction temperature of from about  
4           45°C to about 70°C;  
5           a first cleavage reaction pressure sufficiently high  
6           to maintain the first cleavage reaction mixture  
7           in the liquid phase; and,  
8           a first cleavage reaction residence time effective  
9           to cleave about 95% or more of s-butylbenzene  
10          hydroperoxide in the first cleavage reaction  
11          mixture to phenol and MEK and to cleave about  
12          95% or more of cumene hydroperoxide in the  
13          first cleavage reaction mixture to phenol and  
14          acetone.

1           22. The process of claim 4 wherein the first  
2 cleavage reaction conditions comprise  
3           a first cleavage reaction temperature of from about  
4           45°C to about 70°C;  
5           a first cleavage reaction pressure sufficiently high  
6           to maintain the first cleavage reaction mixture  
7           in the liquid phase; and,  
8           a first cleavage reaction residence time effective  
9           to cleave about 95% or more of s-butylbenzene  
10          hydroperoxide in the first cleavage reaction  
11          mixture to phenol and MEK and to cleave about  
12          95% or more of cumene hydroperoxide in the  
13          first cleavage reaction mixture to phenol and  
14          acetone.

1           23. The process of claim 6 wherein the first  
2 cleavage reaction conditions comprise  
3           a first cleavage reaction temperature of from about  
4           45°C to about 70°C;  
5           a first cleavage reaction pressure sufficiently high  
6           to maintain the first cleavage reaction mixture  
7           in the liquid phase; and,  
8           a first cleavage reaction residence time effective  
9           to cleave about 95% or more of s-butylbenzene  
10          hydroperoxide in the first cleavage reaction

11 mixture to phenol and MEK and to cleave about  
12 95% or more of cumene hydroperoxide in the  
13 first cleavage reaction mixture to phenol and  
14 acetone.

1 24. The process of claim 12 wherein the first  
2 cleavage reaction conditions comprise  
3 a first cleavage reaction temperature of from about  
4 45°C to about 70°C;  
5 a first cleavage reaction pressure sufficiently high  
6 to maintain the first cleavage reaction mixture  
7 in the liquid phase; and,  
8 a first cleavage reaction residence time effective  
9 to cleave about 95% or more of s-butylbenzene  
10 hydroperoxide in the first cleavage reaction  
11 mixture to phenol and MEK and to cleave about  
12 95% or more of cumene hydroperoxide in the  
13 first cleavage reaction mixture to phenol and  
14 acetone.

1 25. The process of claim 23 wherein the first  
2 cleavage reaction temperature is from about 45°C to about  
3 60°C.

1 26. The process of claim 24 wherein the first  
2 cleavage reaction temperature is from about 45°C to about  
3 60°C.

1 27. The process of claim 23 wherein the first  
2 cleavage reaction temperature is from about 45°C to about  
3 55°C.

1 28. The process of claim 24 wherein the first  
2 cleavage reaction temperature is from about 45°C to about  
3 55°C.

1 29. The process of claim 27 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction pressure of about 0.5 atmosphere or more.

1 30. The process of claim 28 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction pressure of about 0.5 atmosphere or more.

1        31. The process of claim 1 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        32. The process of claim 2 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        33. The process of claim 3 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        34. The process of claim 4 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        35. The process of claim 6 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        36. The process of claim 12 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        37. The process of claim 24 wherein the first  
2 cleavage reaction conditions comprise recirculating a  
3 recycle flow of the first cleavage reaction mixture  
4 through the first cleavage reactor.

1        38. The process of claim 31 further comprising  
2 withdrawing the first cleavage reaction product from the  
3 first cleavage reactor at a first cleavage reaction  
4 product withdrawal point upstream of the first cleavage  
5 reactor feed.

1        39. The process of claim 37 further comprising  
2 withdrawing the first cleavage reaction product from the  
3 first cleavage reactor at a first cleavage reaction  
4 product withdrawal point upstream of the first cleavage  
5 reactor feed.

1           40. The process of claim 31 wherein the recycle  
2 flow is greater than the first cleavage reactor feed  
3 flow.

1           41. The process of claim 33 wherein the recycle  
2 flow is greater than the first cleavage reactor feed  
3 flow.

1           42. The process of claim 35 wherein the recycle  
2 flow is greater than the first cleavage reactor feed  
3 flow.

1           43. The process of claim 37 wherein the recycle  
2 flow is greater than the first cleavage reactor feed  
3 flow.

1           44. The process of claim 39 wherein the recycle  
2 flow is greater than the first cleavage reactor feed  
3 flow.

1           45. The process of claim 31 wherein a ratio of the  
2 recycle flow to the first cleavage reactor feed flow is  
3 from about 10:1 to about 100:1 on a weight basis.

1           46. The process of claim 35 wherein a ratio of the  
2 recycle flow to the first cleavage reactor feed flow is  
3 from about 10:1 to about 100:1 on a weight basis.

1           47. The process of claim 31 wherein a ratio of the  
2 recycle flow to the first cleavage reactor feed flow is  
3 from about 20:1 to 40:1 on a weight basis.

1           48. The process of claim 35 wherein a ratio of the  
2 recycle flow to the first cleavage reactor feed flow is  
3 from about 20:1 to 40:1 on a weight basis.

1           49. The process of claim 43 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction residence time effective to cleave from about  
4 95% to about 98% of s-butylbenzene hydroperoxide in the  
5 first cleavage reaction mixture to phenol and MEK.

1           50. The process of claim 41 wherein the first  
2 cleavage reaction residence time is from about 1 minute  
3 to about 10 minutes.

1           51. The process of claim 43 wherein the first  
2 cleavage reaction residence time is from about 1 minute  
3 to about 10 minutes.



1           52. The process of claim 1 wherein the second  
2 cleavage reactor comprises a once through plug flow  
3 reactor.

1           53. The process of claim 35 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1           54. The process of claim 43 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1           55. The process of claim 3 wherein the second  
2 cleavage reaction conditions comprise a second cleavage  
3 reaction temperature and a second cleavage reaction  
4 residence time effective to cleave 95 wt.% or more of the  
5 hydroperoxides remaining in the second cleavage reaction  
6 mixture.

1           56. The process of claim 44 wherein the second  
2 cleavage reaction conditions comprise a second cleavage  
3 reaction temperature and a second cleavage reaction  
4 residence time effective to cleave 95 wt.% or more of the  
5 hydroperoxides remaining in the second cleavage reaction  
6 mixture.

1           57. The process of claim 38 further comprising  
2 withdrawing the first cleavage reaction mixture side  
3 stream between the first cleavage reaction product  
4 withdrawal point and the first cleavage reactor feed  
5 point.

1           58. The process of claim 39 further comprising  
2 withdrawing the first cleavage reaction mixture side  
3 stream between the first cleavage reaction product  
4 withdrawal point and the first cleavage reactor feed  
5 point.

1           59. The process of claim 56 wherein the second  
2 cleavage reaction conditions are effective to convert 70  
3 wt.% or more of DMBA in the first cleavage reaction  
4 product to AMS.

1           60. The process of claim 59 wherein the second  
2 cleavage reaction conditions are effective to convert 70  
3 wt.% or more of EMBA in the first cleavage reaction  
4 product to AES, 2P2B, and combinations thereof.

1        61. The process of claim 56 wherein the second  
2 cleavage reaction conditions are effective to convert 75  
3 wt.% or more of DMBA in the first cleavage reaction  
4 product to AMS.

1        62. The process of claim 59 wherein the second  
2 cleavage reaction conditions are effective to convert 75  
3 wt.% or more of EMBA in the first cleavage reaction  
4 product to AES, 2P2B, and combinations thereof.

1        63. The process of claim 56 wherein the second  
2 cleavage reaction conditions are effective to convert 85  
3 wt.% or more of DMBA in the first cleavage reaction  
4 product to AMS.

1        64. The process of claim 59 wherein the second  
2 cleavage reaction conditions are effective to convert 85  
3 wt.% or more of EMBA in the first cleavage reaction  
4 product to AES, 2P2B, and combinations thereof.

1        65. A process for cleaving one or more  
2 hydroperoxides selected from the group consisting of s-  
3 butylbenzene hydroperoxide, cumene hydroperoxide, and  
4 combinations thereof, the process comprising:

5        feeding to a first cleavage reactor at a first  
6        cleavage reaction feed flow a cleavage reaction  
7        feed comprising from about 0.5 wt.% to 2 wt.%  
8        water, a ketone stream selected from the group  
9        consisting of an acetone stream, a MEK stream,  
10       and a mixed acetone/MEK stream, and an acid  
11       catalyst effective to catalyze the cleavage of  
12       hydroperoxides selected from the group  
13       consisting of s-butylbenzene hydroperoxide,  
14       cumene hydroperoxide, and combinations thereof,  
15       producing a first cleavage reaction mixture  
16       comprising one or more hydroperoxides selected  
17       from the group consisting of said s-  
18       butylbenzene, said cumene hydroperoxide, and  
19       combinations thereof;

20       exposing said first cleavage reaction mixture to  
21       first cleavage reaction conditions effective to  
22       cleave s-butylbenzene hydroperoxide to phenol

23 and MEK and to cleave cumene hydroperoxide to  
24 phenol and acetone,  
25 wherein said first cleavage reaction conditions  
26 comprise:  
27 a first cleavage reaction temperature of less  
28 than 75 °C which is sufficiently high to  
29 cleave a majority of the one or more  
30 hydroperoxides but sufficiently low to  
31 produce a first quantity of non-  
32 recoverable byproducts from components  
33 selected from the group consisting of  
34 dimethylbenzyl alcohol (DMBA), ethyl  
35 methyl benzyl carbinol (EMBA), and  
36 combinations thereof, the first quantity  
37 of said non-recoverable byproducts being  
38 less than a second quantity of said non-  
39 recoverable byproducts produced by the  
40 same process at a cleavage reaction  
41 temperature of 75 °C or higher;  
42 a first cleavage reaction pressure sufficiently  
43 high to maintain the first cleavage  
44 reaction mixture in the liquid phase;  
45 recirculating a recycle flow of the first  
46 cleavage reaction mixture through the  
47 first cleavage reactor, said recycle flow  
48 being greater than the first cleavage  
49 reactor feed flow; and  
50 feeding the first cleavage reaction product to a  
51 second cleavage reactor to produce a second  
52 cleavage reaction mixture;  
53 subjecting the second cleavage reaction mixture to  
54 second cleavage reaction conditions comprising  
55 a second cleavage reaction temperature  
56 effective to cleave a majority of the one or  
57 more hydroperoxides remaining in the second  
58 cleavage reaction mixture, to convert a  
59 majority of DMBA in the second cleavage  
60 reaction mixture to  $\alpha$ -methyl styrene, and to

61           convert a majority of EMBA in the second  
62           cleavage reaction mixture to one or more  
63           compound selected from the group consisting of  
64            $\alpha$ -ethyl styrene (AES), 2-phenyl-2-butene  
65           (2P2B), and combinations thereof, producing a  
66           second cleavage reaction product; and,  
67       subjecting the second cleavage reaction product to  
68           final conditions effective to produce a final  
69           cleavage reaction product comprising phenol and  
70           one or more component selected from the group  
71           consisting of methyl ethyl ketone (MEK),  
72           acetone, and combinations thereof.

1           66. The process of claim 65 wherein a ratio of the  
2       recycle flow to the first cleavage reactor feed flow is  
3       from about 10:1 to about 100:1 on a weight basis.

1           67. The process of claim 65 wherein a ratio of the  
2       recycle flow to the first cleavage reactor feed flow is  
3       from about 20:1 to 40:1 on a weight basis.

1           68. The process of claim 65 wherein the first  
2       cleavage reaction conditions comprise a first cleavage  
3       reaction residence time effective to cleave about 95% or  
4       more of s-butylbenzene hydroperoxide in the first  
5       cleavage reaction mixture to phenol and MEK.

1           69. The process of claim 67 wherein the first  
2       cleavage reaction conditions comprise a first cleavage  
3       reaction residence time effective to cleave about 95% or  
4       more of s-butylbenzene hydroperoxide in the first  
5       cleavage reaction mixture to phenol and MEK.

1           70. The process of claim 65 wherein the first  
2       cleavage reaction conditions comprise a first cleavage  
3       reaction residence time effective to cleave from about  
4       95% to about 98% of s-butylbenzene hydroperoxide in the  
5       first cleavage reaction mixture to phenol and MEK.

1           71. The process of claim 65 wherein the first  
2       cleavage reaction conditions comprise a first cleavage  
3       reaction residence time effective to cleave about 95% or  
4       more of cumene hydroperoxide in the first cleavage  
5       reaction mixture to phenol and acetone.

1           72. The process of claim 68 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction residence time effective to cleave about 95% or  
4 more of cumene hydroperoxide in the first cleavage  
5 reaction mixture to phenol and acetone.

1           73. The process of claim 69 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction residence time effective to cleave about 95% or  
4 more of cumene hydroperoxide in the first cleavage  
5 reaction mixture to phenol and acetone.

1           74. The process of claim 72 wherein the first  
2 cleavage reaction residence time is from about 1 minute  
3 to about 10 minutes.

1           75. The process of claim 73 wherein the first  
2 cleavage reaction residence time is from about 1 minute  
3 to about 10 minutes.

1           76. The process of claim 72 wherein the acid  
2 catalyst is selected from the group consisting of  
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,  
4 and phosphoric acid.

1           77. The process of claim 72 wherein the acid  
2 catalyst comprises sulfuric acid.

1           78. The process of claim 72 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1           79. The process of claim 76 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1           80. The process of claim 77 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1           81. The process of claim 65 further comprising  
2 withdrawing the first cleavage reaction mixture side  
3 stream between the first cleavage reaction product  
4 withdrawal point and the first cleavage reactor feed  
5 point.

1           82. The process of claim 78 further comprising  
2 withdrawing the first cleavage reaction product from the  
3 first cleavage reactor at a first cleavage reaction

4 product withdrawal point upstream of the first cleavage  
5 reactor feed.

1 83. The process of claim 65 wherein the second  
2 cleavage reaction conditions are effective to convert 70  
3 wt.% or more of DMBA in the first cleavage reaction  
4 product to AMS.

1 84. The process of claim 65 wherein the second  
2 cleavage reaction conditions are effective to convert 70  
3 wt.% or more of EMBA in the first cleavage reaction  
4 product to AES, 2P2B, and combinations thereof.

1 85. The process of claim 65 wherein the second  
2 cleavage reaction conditions are effective to convert 75  
3 wt.% or more of DMBA in the first cleavage reaction  
4 product to AMS.

1 86. The process of claim 65 wherein the second  
2 cleavage reaction conditions are effective to convert 75  
3 wt.% or more of EMBA in the first cleavage reaction  
4 product to AES, 2P2B, and combinations thereof.

1 87. The process of claim 65 wherein the second  
2 cleavage reaction conditions are effective to convert 85  
3 wt.% or more of DMBA in the first cleavage reaction  
4 product to AMS.

1 88. The process of claim 65 wherein the second  
2 cleavage reaction conditions are effective to convert 85  
3 wt.% or more of EMBA in the first cleavage reaction  
4 product to AES, 2P2B, and combinations thereof.

1 89. A process for cleaving one or more  
2 hydroperoxides selected from the group consisting of s-  
3 butylbenzene hydroperoxide, cumene hydroperoxide, and  
4 combinations thereof, the process comprising:  
5 feeding a cleavage reaction feed comprising from  
6 about 0.5 wt.% to 2 wt.% water, a ketone stream  
7 selected from the group consisting of an  
8 acetone stream, a MEK stream, and a mixed  
9 acetone/MEK stream, and an acid catalyst to a  
10 first cleavage reactor at a first cleavage  
11 reaction feed flow, producing a first cleavage  
12 reaction mixture, said acid catalyst being  
13 effective to catalyze the cleavage of

hydroperoxides selected from the group  
consisting of s-butylbenzene hydroperoxide,  
cumene hydroperoxide, and combinations thereof;  
exposing said first cleavage reaction mixture to  
first cleavage reaction conditions effective to  
produce a first cleavage reaction product  
comprising the one or more hydroperoxides, said  
first cleavage reaction conditions comprising a  
first cleavage reaction temperature of less  
than 75 °C and a first cleavage reaction  
pressure sufficiently high to maintain the  
first cleavage reaction mixture in the liquid  
phase, said first cleavage reaction conditions  
further comprising recirculating a recycle flow  
of the first cleavage reaction mixture through  
the first cleavage reactor, wherein the ratio  
of said recycle flow to said first cleavage  
reactor feed flow is from about 10:1 to about  
100:1 on a weight basis, said first cleavage  
reaction conditions being effective to cleave  
about 95% or more of s-butylbenzene  
hydroperoxide in the first cleavage reaction  
mixture to phenol and MEK, to cleave about 95%  
or more of cumene hydroperoxide in the first  
cleavage reaction mixture to phenol and  
acetone, and to produce a first quantity of  
non-recoverable byproducts from components  
selected from the group consisting of  
dimethylbenzyl alcohol (DMBA), ethyl methyl  
benzyl carbinol (EMBA), and combinations  
thereof, the first quantity of said non-  
recoverable byproducts being less than a second  
quantity of said non-recoverable byproducts  
produced by the same process at a cleavage  
reaction temperature of 75 °C or higher; and  
feeding the first cleavage reaction product to a  
second cleavage reactor to produce a second  
cleavage reaction mixture;

52           subjecting the second cleavage reaction mixture to  
53           second cleavage reaction conditions comprising  
54           a second cleavage reaction temperature  
55           effective to cleave 95 wt.% or more of the  
56           hydroperoxides remaining in the second cleavage  
57           reaction mixture, to convert 70 wt% or more of  
58           DMBA in the second cleavage reaction mixture to  
59            $\alpha$ -methyl styrene, and to convert 70 wt.% or  
60           more of EMBA in the second cleavage reaction  
61           mixture to one or more compound selected from  
62           the group consisting of  $\alpha$ -ethyl styrene (AES),  
63           2-phenyl-2-butene (2P2B), and combinations  
64           thereof, producing a second cleavage reaction  
65           product; and,

66           subjecting the second cleavage reaction product to  
67           final conditions effective to produce a final  
68           cleavage reaction product comprising phenol and  
69           one or more component selected from the group  
70           consisting of methyl ethyl ketone (MEK),  
71           acetone, and combinations thereof.

1           90. The process of claim 89 wherein said second  
2           cleavage reaction conditions comprise a second cleavage  
3           reaction temperature effective to cleave 95 wt.% or more  
4           of the hydroperoxides remaining in the second cleavage  
5           reaction mixture, to convert 75 wt% or more of DMBA in  
6           the second cleavage reaction mixture to  $\alpha$ -methyl styrene,  
7           and to convert 75 wt.% or more of EMBA in the second  
8           cleavage reaction mixture to one or more compound  
9           selected from the group consisting of  $\alpha$ -ethyl styrene  
10           (AES), 2-phenyl-2-butene (2P2B), and combinations  
11           thereof.

1           91. The process of claim 89 wherein said second  
2           cleavage reaction conditions comprise a second cleavage  
3           reaction temperature effective to cleave 95 wt.% or more  
4           of the hydroperoxides remaining in the second cleavage  
5           reaction mixture, to convert 85 wt% or more of DMBA in  
6           the second cleavage reaction mixture to  $\alpha$ -methyl styrene,  
7           and to convert 85 wt.% or more of EMBA in the second



8 cleavage reaction mixture to one or more compound  
9 selected from the group consisting of  $\alpha$ -ethyl styrene  
10 (AES), 2-phenyl-2-butene (2P2B), and combinations thereof

1 92. The process of claim 89 wherein the first  
2 cleavage reactor is a pipeline loop reactor comprising  
3 one or more heat exchangers effective to maintain a first  
4 cleavage reaction mixture at a first cleavage reaction  
5 temperature.

1 93. The process of claim 90 wherein the first  
2 cleavage reactor is a pipeline loop reactor comprising  
3 one or more heat exchangers effective to maintain a first  
4 cleavage reaction mixture at a first cleavage reaction  
5 temperature.

1 94. The process of claim 91 wherein the first  
2 cleavage reactor is a pipeline loop reactor comprising  
3 one or more heat exchangers effective to maintain a first  
4 cleavage reaction mixture at a first cleavage reaction  
5 temperature.

1 95. The process of claim 89 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 70°C.

1 96. The process of claim 90 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 70°C.

1 97. The process of claim 91 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 70°C.

1 98. The process of claim 92 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 70°C.

1 99. The process of claim 93 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 70°C.

1 100. The process of claim 94 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 70°C.

1        101. The process of claim 89 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 60°C.

1        102. The process of claim 90 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 60°C.

1        103. The process of claim 91 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 60°C.

1        104. The process of claim 92 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 60°C.

1        105. The process of claim 93 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 60°C.

1        106. The process of claim 94 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 60°C.

1        107. The process of claim 91 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 55°C.

1        108. The process of claim 92 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 55°C.

1        109. The process of claim 93 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 55°C.

1        110. The process of claim 94 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction temperature of from about 45°C to about 55°C.

1        111. The process of claim 110 wherein the first  
2 cleavage reaction conditions comprise a first cleavage  
3 reaction pressure of about 0.5 or less.

1        112. The process of claim 89 further comprising  
2 withdrawing the first cleavage reaction product from the  
3 first cleavage reactor at a first cleavage reaction

4 product withdrawal point upstream of the first cleavage  
5 reactor feed.

1 113. The process of claim 111 further comprising  
2 withdrawing the first cleavage reaction product from the  
3 first cleavage reactor at a first cleavage reaction  
4 product withdrawal point upstream of the first cleavage  
5 reactor feed.

1 114. The process of claim 89 wherein a ratio of the  
2 recycle flow to the first cleavage reactor feed flow is  
3 from about 20:1 to 40:1 on a weight basis.

1 115. The process of claim 111 wherein a ratio of the  
2 recycle flow to the first cleavage reactor feed flow is  
3 from about 20:1 to 40:1 on a weight basis.

1 116. The process of claim 111 wherein the first  
2 cleavage reaction residence time is from about 1 minute  
3 to about 10 minutes.

1 117. The process of claim 116 wherein the acid  
2 catalyst is selected from the group consisting of  
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,  
4 and phosphoric acid.

1 118. The process of claim 89 wherein the acid  
2 catalyst comprises sulfuric acid.

1 119. The process of claim 116 wherein the acid  
2 catalyst comprises sulfuric acid.

1 120. The process of claim 89 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1 121. The process of claim 119 further comprising  
2 adding the acid catalyst to a first cleavage reaction  
3 mixture side stream at one or more acid addition points.

1 122. The process of claim 98 further comprising  
2 withdrawing the first cleavage reaction mixture side  
3 stream between the first cleavage reaction product  
4 withdrawal point and the first cleavage reactor feed  
5 point.

1 123. The process of claim 99 further comprising  
2 withdrawing the first cleavage reaction mixture side  
3 stream between the first cleavage reaction product

4 withdrawal point and the first cleavage reactor feed  
5 point.

1 124. The process of claim 122 wherein the amount of  
2 acid catalyst fed to the first cleavage reactor is from  
3 about 0.005% to about 0.1% by weight based on the first  
4 cleavage reactor feed flow.

1 125. The process of claim 123 wherein the amount of  
2 acid catalyst fed to the first cleavage reactor is from  
3 about 0.005% to about 0.1% by weight based on the first  
4 cleavage reactor feed flow.

1 126. The process of claim 89 wherein the second  
2 cleavage reactor comprises a once through plug flow  
3 reactor.

1 127. The process of claim 124 wherein the second  
2 cleavage reactor comprises a once through plug flow  
3 reactor.

1 128. The process of claim 125 wherein the second  
2 cleavage reactor comprises a once through plug flow  
3 reactor.

1 129. The process of claim 89 wherein the second  
2 cleavage reaction conditions comprise a second cleavage  
3 reaction residence time of from about 5 seconds to about 1  
4 minute.

1 130. The process of claim 89 wherein the second  
2 cleavage reaction temperature is from about 60 °C to about  
3 130 °C.

1 131. The process of claim 128 wherein the second  
2 cleavage reaction temperature is from about 60 °C to about  
3 130 °C.

1 132. The process of claim 129 wherein the second  
2 cleavage reaction temperature is from about 60 °C to about  
3 130 °C.

1 133. The process of claim 109 wherein the second  
2 cleavage reaction temperature is from about 70 °C to about  
3 120 °C.

1 134. The process of claim 130 wherein the second  
2 cleavage reaction pressure is about 30 psig or more.

1           135. The process of claim 89 further comprising  
2 taking multiple exotherm measurements to verify the rate  
3 of the cleavage reaction.

1           136. The process of claim 134 further comprising  
2 taking multiple exotherm measurements to verify the rate  
3 of the cleavage reaction.

1           137. The process of claim 135 further comprising  
2 controlling the amount of acid catalyst added to the first  
3 cleavage reaction mixture based on the multiple exotherm  
4 measurements.

1           138. The process of claim 136 further comprising  
2 controlling the amount of acid catalyst added to the first  
3 cleavage reaction mixture based on the multiple exotherm  
4 measurements.

1           139. The process of claim 137 wherein taking the  
2 multiple exotherm measurements comprises  
3 taking a first reaction mixture side stream exotherm  
4 measurement;

5 taking a first cleavage reactor (FCR) exotherm  
6 measurement; and,

7 taking a second cleavage reactor (SCR) exotherm  
8 measurement.

1           140. The process of claim 138 wherein taking the  
2 multiple exotherm measurements comprises

3 taking a first reaction mixture side stream exotherm  
4 measurement;

5 taking a first cleavage reactor (FCR) exotherm  
6 measurement; and,

7 taking a second cleavage reactor (SCR) exotherm  
8 measurement.